82. (New) (New) Apparatus in accordance with claim 1, wherein the source of etchant gas is a source of bromine trifluoride liquid.

83. (New) Apparatus in accordance with claim 38, wherein the etchant is provided from bromine trifluoride in the source chamber.

84. (New) Apparatus in accordance with claim 45, wherein the source of etchant gas comprises a source chamber comprising bromine trifluoride liquid.

85. (New) Apparatus in accordance with claim 47, wherein the source of etchant gas comprises a source of bromine trifluoride liquid.

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86. (New) Apparatus in accordance with claim 56, wherein the source of said fluoride etchant gas comprises bromine trifluoride liquid.

87. (New) Apparatus in accordance with claim 68, wherein the source of etchant gas comprises bromine trifluoride liquid.

88. (New) A method in accordance with claim 22, wherein the source of etchant gas comprises bromine trifluoride.

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89. (New) A method in accordance with claim 26, wherein the solid or liquid etchant comprises ~~xenon difluoride crystals~~ bromine trifluoride.

REMARKS

Claims 1-41 and 45-89 are pending in this application. Claims 42-44 are cancelled herein and claims 74-89 are added

In the December 19, 2002 Office Action, the claims were restricted between two groups (apparatus vs. method) for the reason that the apparatus could be used in a

coating process rather than an etching process. As will be discussed in more detail below, the present invention is distinguishable from the prior art based on the class of etchants used. This feature is brought out in the pending claims by amendments to all the pending independent claims in the present application (except for independent claim 68) – which claims are amended herein to recite an etchant or etchant source of a noble gas halide or halogen halide. This small group of etchants differ from standard plasma etchants in that they can etch a material in a non-plasma state. They are not used for coating processes. Also, it should be mentioned that independent method claim 22 requires an apparatus as set forth in claim 1. In view of the above, though the restriction requirement was likely proper prior to the amendments herein, after the amendments to the claims herein, it is submitted that the search for the two groups (apparatus and method) would now be the same. The Examiner is respectfully requested to reconsider and withdraw the restriction requirement in view of the claims as now pending. As required, the election of Group I is affirmed.

Claims 12-14 were rejected under 35 USC section 112, first paragraph. Claim 12 is amended herein to recite that the gas spreading means is within the etching chamber. Reconsideration and withdrawal of the rejection of claims 12-14 under 35 USC section 112, first paragraph is respectfully requested.

Claims 1, 2, 5, 6, 10, 12, 14-21, 38, 47-52, 54, 55, 68-72 were rejected under 35 USC section 102(b) as being anticipated by JP 09251981 (Kurihara). Claims 1-5, 10, 11, 15-21, 38 and 47-72 were rejected under 35 USC section 102(e) as being anticipated by US patent 6,277,173 to Sadakata et al. Also, claim 1, 2, 6, 7, 10, 12, 13, 15-21, 47-49, 51, 54 and 55 were rejected under 35 USC section 102(b) as being anticipated by US patent 5,206,471 to Smith. (Claim 8 was rejected over Smith in view of Fukumoto or Simmons) These rejections, as applicable to the claims as now pending, are respectfully traversed.

Independent claims 1, 22, 26, 38, 45, 47, 56 and 68 each recite, *inter alia*, a combination of features including an etchant or source of etchant selected from a noble gas halide and a halogen halide. This small class of etchants, sometimes referred to as spontaneous gas phase chemical etchants, are unusual in that they are capable of etching in a non-plasma state. As can be seen by the results of the Examiner's search,

there are very few references on the subject of recirculating etchants in a plasma etching system. There is no prior art, to applicants' knowledge, of recirculating noble gas halide or halogen halides. Noble gas halides and halogen halides ("interhalogens") are conventionally provided via flow-through or pulse systems – never recirculation.

The references cited by the Examiner, namely Kurihara, Sadakata et al. and Smith, each disclose plasma etching systems (see anode electrode 103 in Kurihara, col. 1 lines 23-33 in Sadakata et al., and element 12 in the drawings and col. 1, lines 58-68 in Smith). One of ordinary skill in the art would not be motivated to modify the plasma etching systems of Kurihara, Sadakata or Smith by removing the means for creating the plasma (electrodes, microwave energy source, etc.) as this would destroy the functionality of the systems disclosed therein (e.g. the types of etchants used in these systems will not etch if not energized). Likewise one of ordinary skill in the art would not be motivated to provide a source of noble gas halide or halogen halide to a plasma system such as disclosed in these references. As such, it is submitted that each of the independent claims now pending is nowhere taught or suggested by the prior art. In the same way, each of the claims dependent upon the independent claims as now pending, is allowable for at least the reasons noted above with respect to the independent claims. As such, it is requested that the rejections of the claims under 35 USC section 102 should be withdrawn, and that rejections under 35 USC section 103 would not be warranted due to lack of motivation for modifying the applied references as noted above. Reconsideration and withdrawal of the rejections of the pending claims is respectfully requested.

In the event any fees are required in connection with this response, please charge our Deposit Account No. 501516.

Respectfully submitted,

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MARKED UP COPY OF CLAIM AMENDMENTS

1. Apparatus for etching a sample, said apparatus comprising:

(a) a source of etchant gas selected from a noble gas halide and a halogen halide;

(b) an etching chamber in communication with said source of etchant gas;

(c) a recirculation loop passing through said etching chamber; and

(d) a pump disposed within said recirculation loop for recirculating etchant gas along said recirculation loop.

2. Apparatus in accordance with claim 1 in which said source of etchant gas comprises a source chamber.

3. Apparatus in accordance with claim 2 further comprising an expansion chamber communicating with said source chamber and with a gas source for a gas other than said etchant gas, said expansion chamber arranged for mixing gas from said source chamber with gas from said gas source.

4. Apparatus in accordance with claim 3 in which said expansion chamber is in communication with said recirculation loop.

5. Apparatus in accordance with claim 1 further comprising a filter disposed within said recirculation loop, said filter being one that removes a member selected from the group consisting of byproducts or effluent from gases flowing through said recirculation loop, or particulates.

6. Apparatus in accordance with claim 1 in which said pump is a dry pump.

7. Apparatus in accordance with claim 6 in which said dry pump has no wet seals and adds no gas to said recirculation loop.

8. Apparatus in accordance with claim 7 in which said dry pump is a bellows pump.

9. Apparatus in accordance with claim 8 in which said bellows pump comprises a housing with bellows-type wall sections enclosing a hollow interior, and at least one partition disposed to divide said hollow interior into a plurality of sections.

10. Apparatus in accordance with claim 1 in which said pump is constructed to circulate etchant gas substantially continuously within said recirculation loop.

11. Apparatus in accordance with claim 3 in which said pump is defined as a first pump and said apparatus further comprises a second pump arranged to draw gases from a member selected from the group consisting of said expansion chamber, said source chamber, and said recirculation loop.

12. Apparatus in accordance with claim 2 further comprising gas flow spreading means in said [source] <u>etching</u> chamber for diverting incoming gas.

13. Apparatus in accordance with claim 12 in which said gas flow spreading means is a baffle.

14. Apparatus in accordance with claim 12 in which said gas flow spreading means is a perforated plate.

15. Apparatus in accordance with claim 1, further comprising an energy source and/or electric field source at the etching chamber for forming a plasma therein.

16. Apparatus in accordance with claim 2 in which said source of etchant gas further comprises fluoride crystals retained within said source chamber.

17. Apparatus in accordance with claim 16 in which said fluoride crystals are xenon difluoride crystals.

18. Apparatus in accordance with claim 3 in which said gas source for a gas other than said etchant gas comprises a source of a gas with molar averaged molecular weight less than or equal to that of N2.

19. Apparatus in accordance with claim 18 in which said gas other than said etchant gas is a member selected from the group consisting of Ar, Ne, He and N2.

20. Apparatus in accordance with claim 3 in which said gas source for a gas other than said etchant gas comprises a plurality of gas sources, the gases from which, when mixed, yield a gaseous mixture with molar averaged molecular weight less than or equal to that of N2.

21. Apparatus in accordance with claim 20 in which said plurality of gas sources are sources of two or more members selected from the group consisting of Ar, Ne, He and N2.

22. A method for etching a sample, said method comprising:

(a) placing said sample in an etching chamber disposed within a gas recirculation loop, said etching chamber

in communication with a source of etchant gas selected from a noble gas halide and a halogen halide, and said gas recirculation loop having a pump disposed therein;

(b) passing etchant gas from said source of etchant gas into said etching chamber to expose said sample to said etchant gas; and

(c) recirculating said etchant gas through said recirculation loop by way of said pump.

23. A method in accordance with claim 22 further comprising passing said etchant gas through an expansion chamber prior to step (b) and, while said etchant gas is in said expansion chamber, forming a mixture of said etchant gas with non-etchant gases, and step (b) comprises passing said etchant gas as part of said mixture into said etching chamber.

24. A method in accordance with claim 22 in which said pump is a continuous recirculation pump and step (c) comprises continuously recirculating said etchant gas through said recirculation loop.

25. A method in accordance with claim 22 further comprising bleeding etchant gas into said recirculation loop during step (c).

26. A method comprising:

providing an apparatus according to claim 1;

providing a solid or liquid etchant selected from a noble gas halide and a halogen halide at said etchant

source at a temperature and pressure sufficient to cause said etchant to vaporize;

providing a sample to be etched within the etching chamber;

passing the vaporized etchant through the etching chamber; and

recirculating the etchant multiple times through the etching chamber with said pump.

27. A method in accordance with claim 26, wherein the etchant gas is passed through the pump without additional gas being added thereto.

28. A method in accordance with claim 26, wherein the source of etchant gas comprises two chambers, wherein the temperature and/or pressure of one chamber is different from the pressure and/or temperature of the other so that predominantly liquid or solid etchant remains in one chamber and predominantly gas etchant is in the other, prior to passing into the recirculation path and etching chamber.

29. A method in accordance with claim 26 comprising heating the process gas so as to at least avoid condensation, and cooling the etching chamber and/or sample to improve selectivity between the silicon and non-silicon portions of the sample.

30. A method in accordance with claim 26 in which said sample comprises a silicon portion existing in at least one layer and one or more non-silicon portion existing in at least one layer, said silicon etchant is a fluoride gas selected from the group consisting of noble gas fluorides and halogen fluorides, and said gas is a gas mixture which further comprises a non-etchant gas additive at a partial pressure

and a molar ratio relative to said fluoride gas such that said gas mixture achieves substantially greater etching selectivity toward said silicon portion than would be achieved with said fluoride gas alone.

31. A method in accordance with claim 30 in which said non-etchant gas additive is a member selected from the group consisting of nitrogen, argon, helium, neon, and mixtures thereof.

32. A method in accordance with claim 30 in which said non-etchant gas additive is a member selected from the group consisting of helium, a mixture of helium and nitrogen, and a mixture of helium and argon.

33. A method in accordance with claim 30 in which said fluoride is a xenon fluoride and said non-etchant gas additive is helium.

34. A method in accordance with claim 30 in which said non-silicon portion is a member selected from the group consisting of titanium, gold, tungsten, and compounds thereof.

35. A method in accordance with claim 30 in which said silicon portion is a silicon layer deposited over a substrate and said non-silicon portion is a layer of a member selected from the group consisting of silicon nitride, silicon carbide, and silicon oxide, deposited over said silicon layer, said non-silicon layer being patterned to leave vias therein for access of said gas to said silicon layer, the exposure of said sample to said gas being of sufficient duration to laterally etch away substantially all of said silicon layer by access through said vias.

36. A method in accordance with claim 26 in which said sample is a substrate for a member selected from the group consisting of a semiconductor and/or a MEMS device.

37. A method in accordance with claim 26 in which said sample is a substrate for a MEMS device.

38. Apparatus for exposing a silicon-containing sample to a gas comprising a gaseous fluoride etchant <u>selected from a noble gas fluoride and a halogen fluoride</u> for etching silicon, said apparatus comprising:

a flow-through etching chamber comprising:

a sample support,

entry and exit ports for said gas;

a source chamber comprising a <u>noble gas fluoride or halogen</u> fluoride etchant in solid or liquid form, the source chamber and the etching chamber capable of being in fluid communication with each other;

a recirculation loop and recirculation pump within the loop, the recirculation loop constructed to connect to the etching chamber at two locations to allow etching gas to flow into and out of the etching chamber, and the recirculation pump in communication with the etching chamber and adapted to pump etching gas repeatedly through the etching chamber.

39. Apparatus in accordance with claim 38 further comprising a baffle and perforated plates comprising parallel circular plates arranged coaxially within said flow-through chamber.

40. Apparatus in accordance with claim 39 in which said perforations in said perforated plate are of decreasing diameter from the center of said perforated plate outward.

41. Apparatus in accordance with claim 40, further comprising a plasma generator at said etching chamber.

45 Apparatus for etching silicon from a sample by exposing said sample to a gas comprising a silicon etchant selected from a noble gas halide and a halogen halide, said apparatus comprising:

a source of etchant gas selected from a noble gas halide and a halogen halide;

a flow-through chamber having:

a sample support,

entry and exit ports for said gas,

a perforated plate between said entry port and said sample support, and

a baffle between said entry port and said perforated plate, said baffle positioned to deflect said etchant gas from said etchant port radially toward the periphery of said perforated plate, and said perforated plate containing an array of perforations arranged to distribute said deflected etchant gas over all exposed surfaces of said sample; and

a reciprocating pump driving said gas toward said entry port, said

reciprocating pump comprising:

an enclosed housing comprising bellows-type wall sections and a partition arranged to divide the interior of said housing into first and second chambers, said partition being movable in a reciprocating manner to cause collapse and extension of said bellows-type wall sections whereby one chamber contracts while the other expands and vice versa;

inlet and outlet ports for each chamber with controllable shutoff valves at each port; and

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an enclosed housing comprising bellows-type wall sections and a partition arranged to divide the interior of said housing into first and second chambers, said partition being movable in a reciprocating manner to cause collapse and extension of said bellows-type wall sections whereby one chamber contracts while the other expands and vice versa;¶
inlet and outlet ports for each chamber with controllable shutoff valves at each port; and¶
a partition driver for moving said partition in a reciprocating manner and opening and closing said shutoff valves in a coordinating sequence, causing said chambers to draw fluid in through alternating inlet ports while discharging fluid through alternating outlet ports and thus together to produce a substantially continuous outlet flow.¶
43.. A reciprocating pump in accordance with claim 42 in which all surfaces of said bellows-type wall sections, said partition, and any other components that face the interior of said chambers are of material that is resistant to corrosion by noble gas fluorides and halogen fluorides.¶
44.. A reciprocating pump in accordance with claim 42 in which said chambers are sized and said partition driver is selected to achieve a pumping rate of from about 3 liters per minute to about 300 liters per minute.¶

a partition driver for moving said partition in a reciprocating manner and opening and closing said shutoff valves in a coordinating sequence, causing said chambers to draw fluid in through alternating inlet ports while discharging fluid through alternating outlet ports and thus together to produce a continuous outlet flow.

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46. Apparatus in accordance with claim 45 in which said reciprocating pump draws gas from said exit port.

47.. Apparatus for adding or removing a layer of material from a sample by contacting said sample with a process gas, said layer having at least one dimension less than 1mm, said apparatus comprising:

(a) a source of said process gas selected from a noble gas halide and a halogen halide;

(b) a fabrication chamber in communication with said source of process gas;

(c) a recirculation loop passing through said fabrication chamber; and

(d) a pump disposed within said recirculation loop for recirculating process gas along said recirculation loop.

48. Apparatus in accordance with claim 47 in which said process gas corrodes metal in the presence of moisture.

49. Apparatus in accordance with claim 48 in which said moisture is water moisture.

50. Apparatus in accordance with claim 47 further comprising a filter disposed within said recirculation loop, said filter being one that removes a member selected from the group consisting of byproducts, particulates or effluents from gases flowing through said recirculation loop.

51. Apparatus in accordance with claim 47 in which said source of process gas is comprised of a member selected from the group consisting of (i) chamber retaining a said process gas and a condensed liquid phase of said process gas in equilibrium with said process gas, (ii) a pressurized chamber of said process gas, and (iii) a chamber retaining a solid condensed phase of said process gas.

52. Apparatus in accordance with claim 47 in which said source of process gas is comprised of first and second chambers, said first chamber retaining primarily a liquid or solid condensed form of said process gas, and said second chamber retaining said process gas evaporated or sublimed from said condensed form, said first and second chambers being maintained at different temperatures.

53. Apparatus in accordance with claim 51 further comprising a source of pressurized diluent gas and an expansion chamber positioned to receive diluent gas from said source of diluent gas and process gas from said source of process gas and to mix said diluent gas and said process gas thus received.

54. Apparatus in accordance with claim 47 in which said layer has at least one dimension less than 500μm.

55. Apparatus in accordance with claim 47 in which said layer has at least one dimension less than 100μm.

56. Apparatus for etching a sample by contacting the sample with a vapor fluoride etchant gas selected from a noble gas fluoride and a halogen fluoride:

(a) a source of said fluoride etchant gas, said source of etchant gas being comprised of first and second chambers, said first chamber retaining primarily a liquid or solid condensed form of said fluoride etchant gas, and said second chamber retaining said fluoride etchant gas volatilized from said condensed form, said source comprising a temperature regulator for maintaining the first and second chambers at different temperatures;

(b) an etching chamber in communication with said source of fluoride etchant gas for holding the sample to be etched by the fluoride etchant gas.

57. Apparatus in accordance with claim 57, in the absence of a source of energy for energizing the etchant gas once in gas form.

58 Apparatus in accordance with claim 57, wherein the first source chamber is held at a temperature less than the second source chamber.

59. Apparatus in accordance with claim 59, wherein the two source chambers are maintained at more than 3 degrees C difference.

60. Apparatus in accordance with claim 59, wherein both source chambers are maintained at temperatures under 40 degrees C.

61. Apparatus in accordance with claim 58, further comprising a recirculation path for recirculating the fluoride etchant gas repeatedly through the etching chamber.

62. Apparatus in accordance with claim 57, wherein the first source chamber comprises primarily liquid or crystals of a halogen or noble gas fluoride.

63. Apparatus in accordance with claim 57, further comprising a cooling unit for cooling the process gas, one or more of the aforementioned chambers and/or the sample being etched.

64. Apparatus in accordance with claim 64, wherein the cooling unit is adapted to cool the process gas, one or more of the aforementioned chambers and/or sample below room temperature.

65. Apparatus in accordance with claim 65, wherein the cooling unit is adapted to cool in the range of from about 1 to 15 degrees C.

66. Apparatus in accordance with claim 57, wherein the sample comprises silicon and one or both of a dielectric and a metal, and the silicon is etched relative to the dielectric and/or metal.

67. Apparatus in accordance with claim 67, wherein the dielectric is a silicon nitride or silicon oxide layer.

68. Apparatus for etching a sample comprising a silicon material and a dielectric material, comprising:

a source of a noble gas halide and/or halogen halide etchant gas;

an etching chamber in communication with the source of the etchant gas;
a surface within the etching chamber for holding the sample to be etched;
a cooling unit for cooling the surface, etching chamber and/or etchant gas below room temperature.

69. Apparatus according to claim 69, wherein the source comprises a source chamber having therein a liquid or solid noble gas halide or halogen halide.

70. Apparatus according to claim 70, wherein the source chamber comprises xenon difluoride crystals and/or bromine trifluoride liquid.

71. Apparatus according to claim 71, comprising a second source chamber connected to said source chamber and maintained at a temperature higher than the temperature of said source chamber.

72. Apparatus according to claim 69, further comprising a sample held by a holder, the sample comprising a sacrificial silicon portion and a dielectric portion.

73. A method in accordance with claim 26, wherein the etchant gas is passed through a baffle and a perforated plate within the etching chamber.

74. Apparatus in accordance with claim 1, wherein the source of etchant gas is a source of xenon difluoride crystals.

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75. Apparatus in accordance with claim 38, wherein the etchant is provided from xenon difluoride crystals in the source chamber.

76. Apparatus in accordance with claim 45, wherein the source of etchant gas is a source chamber comprising xenon difluoride crystals.

77. Apparatus in accordance with claim 47, wherein the source of etchant gas is a source of xenon difluoride crystals.

78. Apparatus in accordance with claim 56, wherein the source of said fluoride etchant gas comprises xenon difluoride crystals.

79. Apparatus in accordance with claim 68, wherein the source of etchant gas comprises xenon difluoride crystals.

80. A method in accordance with claim 22, wherein the source of etchant gas comprises xenon difluoride.

81. A method in accordance with claim 26, wherein the solid or liquid etchant comprises xenon difluoride crystals.

82. Apparatus in accordance with claim 1, wherein the source of etchant gas is a source of bromine trifluoride liquid.

83. Apparatus in accordance with claim 38, wherein the etchant is provided from bromine trifluoride in the source chamber.

84. Apparatus in accordance with claim 45, wherein the source of etchant gas comprises a source chamber comprising bromine trifluoride liquid.

85. Apparatus in accordance with claim 47, wherein the source of etchant gas comprises a source of bromine trifluoride liquid.

86. Apparatus in accordance with claim 56, wherein the source of said fluoride etchant gas comprises bromine trifluoride liquid.

87. Apparatus in accordance with claim 68, wherein the source of etchant gas comprises bromine trifluoride liquid.

88. A method in accordance with claim 22, wherein the source of etchant gas comprises bromine trifluoride.

89. A method in accordance with claim 26, wherein the solid or liquid etchant comprises xenon difluoride crystals.

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